Limited Tillage of Furrow Irrigated Winter Wheat

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CONTINUOUS cropped winter wheat was successfully managed with furrow irrigation by use of limited tillage and chemical weed-volunteer control on the Southern High Plains. No-till had slightly higher yields and irrigation water use efficiency than did clean tillage. The yield increase with no-till was generally offset by additional cost of herbicides. Limited tillage seemed more practical and dependable as an alternative to clean tillage. No-till and limited tillage reduced time and fuel requirements by 50 and 40 percent, respectively.

INTRODUCTION

Approximately 500,000 ha of irrigated wheat on the Southern High Plains produces 5,000 to 10,000 kg/ha of crop residue. Conventional practice has been to perform several tillage operations to incorporate residue, control weeds and crop volunteer, and prepare a seedbed for the next crop. The wheat residue is ocasionally burned as an expedient. The between-crop tillage period is from harvesting in June until seeding time for the next crop, usually in September.

A study at Bushland, Texas showed that irrigated wheat can be produced successfully under a wide range of tillage operations including limited tillage (Unger et al. 1973). During 1970 to 1971, exploratory research showed that continuous irrigated wheat could be successfully seeded by no-till methods. Weeds and volunteer wheat between harvest and seeding were controlled with 2,4-D and a contact herbicide [paraquat (1.1′-dimethyl-4.4′-dipyridinium ion)]. Grain yields of no-till seeded wheat were increased 850 kg/ha, primarily by snow trapping in standing stubble which prevented freeze damage when temperatures dipped to -23 C on three consecutive days. Results of the exploratory research led to the initiation of this study with limited tillage on furrow irrigated winter wheat. The objectives were to determine the effect of reduced tillage with associated chemical weed and volunteer control upon (a) seeding, plant establishment, growth, yield, and irrigation water use efficiency, and(b) the time of field operation, fuel requirements, and variable production costs.

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PROCEDURE

The study was established on old bed-furrows with moderate stubble (approximately 6,000 kg/ha) after harvesting the 1971 wheat crop. The soil, a fine textured and slowly permeable Pullman clay loam, occurs on approximately 1.2 million ha of furrow irrigated land in the Southern High Plains. The soil was described by Taylor, et al., (1963). The experiment was a randomized block, split plot design, with three replicates and was established on 210-m furrows with 0.8 percent grade. Main plot treatments were irrigation level and subplot treatments were tillage. Main plots were 210 m long by twenty-four 1-m bed-furrows wide. Subplots were 8 bed-furrows wide. The three tillage treatments were evaluated under two irrigation levels, adequate (I-A) and limited (I-L). Adequate and limited irrigation levels averaged four and two spring applications, respectively. The tillage treatments were as follows:

T-1 — No-Tillage

Application of 2,4-D in early July, contact herbicide in August, and anhydrous ammonia (NH_3) furrow chiseled before seeding.

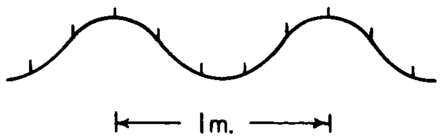

FIG. 1 Bed-furrow configuration showing location of wheat drill rows.

T-2 — Limited Tillage

Application of 2,4-D in early July, disk bed in August, furrow chisel NH_3, and sweep-rod weeder cultivation before seeding. The rod undercut the beds and the sweeps cleaned the furrows.

T-3 — Clean-Tillage (Control)

Tandem disk in early July to level old beds, chisel 20 cm deep, disk in August, disk bed, furrow chisel NH_3, and sweep-rod weeder cultivation before seeding.

The T-1 and T-2 treatments were alternated annually so that the T-2 disk bedding operation could be used to reform beds and furrows the next year after the T-1 test. Anhydrous ammonia was applied yearly at 120 kg N/ha. Plots were seeded with a (20 by 8) single disk grain drill having 20-cm spaced disk-openers. Three drill rows each were located on the bed and two in the furrow (Fig. 1). The drill rows on the bed were located with one row at the crown and a row on each side. Disk openers, operating on the sides of the bed, were positioned so that the concave side of the disk faced toward the bed which helped to maintain bed shape. The wheel spacing on the (20 by 8) end-wheel grain drill were about 4 m, which fitted every fourth furrow.

Caprock, Tamwheat-101, and Centurk were seeded in 1971, 1972, and 1973, respectively, at 70 kg/ha. Seeding dates were August 27, September 27, and October 2, respectively, in 1971 to 1973. Irrigation water inflow rates were measured and adjusted to individual furrows through gated pipe (Allen and Musick 1972). Portable "H" flumes equipped with water level recorders were used to measure furrow runoff. Harvest dates

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were June 20, 29, and 25, respectively, during 1972 to 1974. Yield samples were obtained from 4- by 30-m areas with a combine at the upper, middle, and lower section of each subplot. Time required for tillage operations and fuel consumption was recorded.

RESULTS AND DISCUSSION

Weed and Volunteer Wheat Control

The effectiveness of herbicides in controlling crop volunteer and weeds varied between years. With T-1, broadleaf weeds were generally controlled by applying 2,4-D at 0.60 kg/ha after wheat harvest. The contact herbicide, paraquat, controlled remaining weeds and volunteer well in 1971 when all vegetation was killed before seeding. In 1972, above average August rainfall caused vigorous weed growth and one application of paraquat provided only 60 percent control, so a second application was necessary. In 1973, glyphosate [N-(phosphonomethyl) glycine] provided good control before seeding but required 7 days to kill vegetation. Results with paraquat, though erratic, were apparent within 24 hrs. The furrow injection of NH_3 with narrow chisel points provided the only tillage effect on the T-1 treatment.

With T-2, the disk bedding operation satisfactorily cleaned the furrows and reshaped old beds. The disk bedder controlled crop volunteer and weeds in the furrow and on the side of the beds, however, growth on top of the beds was not completely controlled. A succeeding sweep-rod weeder cultivation successfully controlled the vegetation remaining on the beds. A second sweep-rod weeder cultivation was usually necessary just before seeding to insure control of late emerging weeds and volunteer wheat.

With the T-3 control, disking in two directions at right angles successfully leveled the bed-furrows from the previous crop, loosened the surface soil to 10 cm deep, and incorporated residue. A third disking was necessary to control crop volunteer and weeds before new beds were formed in late August. The sweep-rod weeder cultivation before seeding controlled any remaining growth and firmed the beds which resulted in a suitable seedbed. The planned 20-cm chiseling was not done before seeding the 1971-72 crop because the implement was not available in time. In July and August of 1972, soil conditions were too wet for chiseling. In the summer of 1973, chiseling provided satisfactory soil loosening to 20 cm deep.

TABLE 1. WHEAT YIELD, IRRIGATION WATER INTAKE, SEASONAL PRECIPITATION, IRRIGATION WATER USE AND EFFICIENCY, 1972 to 1974

Treatment		Yield	Irrigation intake	Precipitation Seed-Harvest	Irrigation water use efficiency
		kg/ha	cm	cm	kg/m^3
1971-72					
Dryland		1,300			
I-A*	T-1*	3,600 a†	35.6 a†	37.1	0.646 a†
	T-2	3,210 b	36.8 a		0.519 d
	T-3	3,020 bc	38.7 a		0.444 e
I-L	T-1	2,940 bc	25.3 b		0.648 a
	T-2	2,740 cd	24.4 b		0.590 c
	T-3	2,340 e	24.6 b		0.423 e
1972-73					
Dryland		2,180			
I-A	T-1	4,230 a	33.6 a	41.3	0.610 a
	T-2	3,840 b	36.9 a		0.450 c
	T-3	3,770 b	34.0 a		0.468 c
I-L	T-1	4,070 ab	33.5 a		0.564 b
	T-2	3,860 b	36.3 a		0.463 c
	T-3	3,640 b	37.1 a		0.394 d
1973-74					
Dryland		340			
I-A	T-1	2,100 a	37.7 b	22.1	0.467 d
	T-2	2,130 a	32.3 c		0.554 c
	T-3	2,270 a	44.5 a		0.434 d
I-L	T-1	1,730 b	21.4 e		0.650 b
	T-2	1,750 b	18.9 e		0.746 a
	T-3	1,860 b	26.7 d		0.569 c
Average					
I-A	T-1	3,310 a	35.6 b		0.574 a
	T-2	3,060 ab	35.3 b		0.508 b
	T-3	3,020 ab	39.0 a		0.450 bc
I-L	T-1	2,910 b	26.7 d		0.620 a
	T-2	2,780 bc	26.5 d		0.600 a
	T-3	2,610 c	29.5 c		0.462 bc

*I-A = adequate irrigation; I-L = limited irrigation; T-1 = no tillage; T-2 = limited tillage; T-3 = clean tillage control.
†Column values for individual years followed by the same letter are not significantly different at the 5 percent level.

Seeding, Stand Establishment, and Growth

The grain drill seeding operation, seedling emergence, and stand establishment were satisfactory for all treatments in 1971 and 1972. The disk openers penetrated through the residue on the T-1 treatment in 1971 and 1972, however, in 1973, the large amount of residue (approximately 10,000 kg/ha) limited disk opener penetration. This condition resulted in variable stands in some no-till furrows.

Fall growth was similar for all treatments during the study. Spring growth, heading, and grain filling were comparable for all tillage treatments that were adequately irrigated. Limited irrigation resulted in less plant tillering, less stem elongation, smaller heads, and less grain filling for the 1971-72 and 1973-74 crops. Above average rainfall in the early spring of 1973, resulted in only slight differences in plant growth and grain development between the two irrigation levels for the 1972-73 crop.

Yields

Seasonal growing conditions and yield levels varied among years in the study (Table 1). In 1971-72, an average crop season, yields ranged from 2,300 to 3,600 kg/ha. Yields significantly increased as the amount of tillage decreased under both irrigation levels. Yield of T-1 with only limited irrigation was nearly equal to the adequately irrigated T-3 treatment. Each tillage treatment responded to adequate irrigation.

In 1972-73, the yield range was less (3,600-4,200 kg/ha). With adequate irrigation, T-1 yielded significantly more than did T-2 or the T-3 control. Differences in yield between irrigation levels were not significant, which is attributed to above average rainfall and low irrigation requirements in spring 1973.

TABLE 2. NUMBER OF YEARLY IRRIGATION APPLICATIONS

Year	Irrigation treatment	Irrigation applications	
		Fall	Spring
1971-71	I-A	0	5
	I-L	0	3
1972-72	I-A	1	2
	I-L	1	1
1973-74	I-A	0	5
	I-L	0	3

In 1973-74, there was no yield response to tillage. Yields were adversely affected by greenbug infestation and late season hail damage. Damage was uniform over the plot area so relative treatment comparisons should be valid.

Yield increases with T-2 and T-1 over the control in 2 of the 3 yrs were the result of more soil moisture available in storage from seeding time through winter and into early spring. Average grain yields for the 3 yrs were not significantly affected by tillage under adequate irrigation. With limited irrigation, T-1 averaged significantly more (300 kg/ha) than did T-3.

Irrigation

No problems were experienced in irrigating through the no-till furrows as compared with clean tillage. Irrigation water requirements varied between years. The numbers of fall and spring irrigations applied are shown in Table 2.

In the 1971-72 and the 1973-74 seasons, no fall irrigations were needed. Early spring warmup and regrowth required five and three spring irrigations, respectively, for the adequate and limited levels. In the 1972-73 season, a fall irrigation was required to insure emergence and establish the crop. Above average precipitation during the following March and April delayed the need for irrigation until May which was a period of head development and early grain filling. Only one and two spring irrigations, respectively, were needed for the limited and adequate irrigation levels with intake being about equal for both treatments. This was the result of greater soil cracking on the limited irrigation plots. There was no significant difference in irrigation water intake caused by tillage for the 1971-72 and 1972-73 crops. In 1973-74, T-3 had significantly more intake under both irrigation levels. This was the result of the soil loosening caused by chiseling.

Irrigation water use efficiencies reflect the yield increase, per unit of irrigation water, above that of continuous dryland wheat. This is expressed in kg per cubic meter of irrigation water. In 1971-72 and 1972-73, T-1 resulted in significantly higher irrigation water use efficiency. In 1973-74, T-2 was most efficient. The higher irrigation efficiency is related to lower irrigation intake in each year. T-1 averaged significantly higher irrigation water use efficiency than did T-3 under both irrigation levels.

TABLE 3. AVERAGE TIME AND DIESEL FUEL CONSUMPTION RATES, FURROW IRRIGATED CONTINUOUS WHEAT, FINE TEXTURED SOIL, SOUTHERN HIGH PLAINS, 56-kw (75-hp) TRACTOR, 4-ROW EQUIPMENT

Operation	No-till		Limited till		Clean-till	
	Time	Fuel	Time	Fuel	Time	Fuel
	hr/ha	liter/ha	hr/ha	liter/ha	hr/ha	liter/ha
Disk x (3)					1.8	28.0
Spray 2,4-D	0.50*	3.6*	0.50*	3.6*	0.25†	1.8†
Disk-bed			0.50	8.5	0.50	8.5
Spray contact herbicide	0.25	1.8				
Fert. (NH_3)	0.60	7.5	0.60	7.5	0.60	7.5
Rod weeder			0.60	8.0	0.60	8.0
Seeding	0.60	3.7	0.60	3.7	0.60	3.7
Harvest	0.60	10.0	0.60	10.0	0.60	10.0
Total	2.55	26.6	3.40	41.3	4.95	67.5
Herbicide adjustment‡		14.0		5.6		2.8
Adjusted Total	2.55	40.6	3.40	46.1	4.95	69.5

*Two applications of 2,4-D. One after harvest and one in early spring to control annual broadleaf weeds.
†One application of 2,4-D in early spring.
‡Herbicide energy equivalent expressed as diesel fuel in liters/ha.

Equipment, Time, Fuel Requirements, and Costs

The three tillage treatments can also be compared on the basis of the time for operations, related fuel consumption, and costs. Table 3 shows the time requirements and fuel consumption rates using 4-row equipment and a 56-kw (75-hp) tractor. These include all operations through harvest, but not transportation of grain. The respective time requirements for T-2 (3.4 hr/ha) and T-3 (5 hr/ha), were 1.4 and 2 times greater than T-1 (2.5 hr/ha).

Differences in fuel consumption for the treatments varied proportionately with the time required. The total fuel consumed represents the relative amounts that a farmer would use to produce the crop with the different tillage systems. The adjusted fuel total includes equivalent energy required to produce the herbicides (Clark and Johnson 1975), expressed in liters/ha of diesel fuel for convenience of comparison. The adjusted fuel totals for treatments T-1 and T-2 are about equal at 45 liters/ha or 65 percent of that required for T-3.

Costs of herbicide, fuel, and labor are compared in Table 3. Other costs were not significantly different between treatments and are not included. For T-1, T-2, and T-3 treatments, costs were \$42.85/ha, \$21.70/ha, and \$28.50/ha, respectively. The T-1 treatment cost \$21.15/ha more than T-2, but produced \$27.60/ha more based on a \$0.11/kg (\$3.00/bu) wheat price. The \$6.45/ha added return with T-1 is not considered worth the risk of depending on contact herbicide. One application of contact herbicide may not be enough for control in some years, as happened in the second year of this study. The T-2 treatment cost about \$7.00/ha less than T-3 without any decrease in average yield. Limited tillage, as practiced in this study, is a more practical alternative to clean tillage than is no-till.

SUMMARY AND CONCLUSIONS

Continuous cropped winter wheat was successfully managed with furrow irrigation using limited tillage and

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TABLE 4. VARIABLE COSTS OF LABOR, FUEL, AND HERBICIDES, FURROW IRRIGATED CONTINUOUS WHEAT, FINE TEXTURED SOIL, SOUTHERN HIGH PLAINS, 56-kw (75-hp) TRACTOR, 4-ROW EQUIPMENT

Producer's costs	No-till	Limited-till	Clean-till
	$/ha	$/ha	$/ha
Labor*	10.20	13.60	19.80
Fuel†	2.65	4.10	6.70
Herbicides	30.00	4.00	2.00
Total	42.85	21.70	28.50

*Labor = \$4.00/hr.
†Fuel = \$0.10/liter.

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chemical weed-volunteer control in the Southern High Plains. Wheat grown with clean tillage was used for comparison. Climate, resulting grain yield, irrigation water intake, and water use efficiency were variable among years. No-till had slightly higher yields and irrigation water use efficiency than did clean tillage over the 3-yr study.

A contact herbicide (paraquat) for between-crop weed and volunteer control was only about 60 percent effective during 1 year. Chisel application of anhydrous ammonia in furrows was satisfactory on all treatments. Seeding through moderate standing residue was satisfactory in 2 of the 3 yrs. Relatively heavy residue in 1 yr limited disk opener penetration of the grain drill and resulted in variable plant stands, although grain yields were not reduced significantly.

No-till and limited tillage required fewer operations between crops which reduced time and fuel requirements by about 50 and 40 percent, respectively. The contact herbicide cost for no-tillage was about $30.00/ha. This added cost was generally offset by the slight yield increase with no-till, grossing $6.00/ha more than limited tillage.

Limited tillage costs about $7.00/ha less than did clean tillage while average grain yields remained about the same. Limited tillage seemed more practical and dependable as an alternative to clean tillage for a continuous wheat system. With no-till, the potential yield increase of a wheat crop may not be worth the risk of relying upon total chemical weed and volunteer control.

References

1 Allen, R. R. and J. T. Musick. 1972. Wheat and grain sorghum irrigation in a wide bed-furow system. TRANSACTIONS of the ASAE 15(1):61-63.

2 Clark, S. J. and W. H. Johnson. 1975. Energy-cost budgets for grain sorghum tillage systems. TRANSACTIONS of the ASAE 18:1057-1060.

3 Taylor, H. M., C. E. Van Doren, C. L. Godfrey, and J. R. Coover. 1963. Soils of the Southwestern Great Plains Field Station. Texas Agr. Exp. Sta. Misc. Pub. 669.

4 Unger, P. W., R. R. Allen, and J. J. Parker. 1973. Cultural practices for irrigated winter wheat production. Proc. of the SSSA 37(3):437-442.